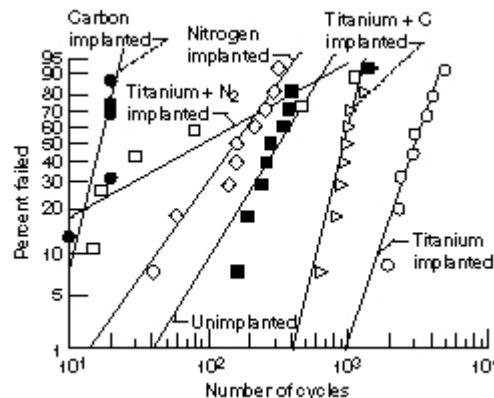


Ion Implantation of Perfluoropolyether-Lubricated Surfaces for Improved Tribological Performance

For over 30 years, perfluoropolyethers (PFPE's) have been the liquid lubricants of choice for space applications because of their proven tribological performance and desirable properties, such as low vapor pressure and a wide liquid temperature range. These oils are used in such space mechanisms as gyroscopes, scanning mirrors, actuators, and filter wheels. In the past few years, there have been several incidents during which PFPE-lubricated space mechanisms have shown anomalous behavior. These anomalies are thought to be the result of PFPE degradation.

Investigative research focused on understanding and modeling the degradation of PFPE lubricants has shown that PFPE's degrade and lose their desirable properties while under boundary-lubricated, sliding/rolling contacts and at elevated temperatures. These performance deficiencies are strongly dependent on the surface chemistry and reactivity of the lubricated contacts, which dictate the formation of harmful catalytic byproducts. One way to inhibit tribo-induced degradation may be to use passivated surfaces that do not promote the formation of harmful byproducts. Such a passivated surface would inhibit PFPE degradation and increase the lifetime of the lubricated mechanism.

Ion implantation is one such passivation technique. This surface-treatment technique can modify the surface properties of materials without affecting either the properties or dimensions of the bulk material beneath the treated layer. By introducing a foreign species into a submicron surface layer, ion implantation can induce unique surface microstructures.



Effect of ion implantation on Weibull distribution lifetimes for lubricated disks.

One notable study conducted by engineers from the NASA Lewis Research Center, Colorado State University, and Colorado School of Mines shows promise in enhancing PFPE-lubricating longevity by passivating the mating surfaces via ion implantation. In this study, thin films of a commercial PFPE lubricant were investigated in the presence of ion-implanted 440C steel. Stainless steel samples were implanted with either N₂, C, Ti, Ti +

N₂, or Ti + C. The PFPE (60- to 400-angstroms thick) was applied uniformly across the surface; then, the steel was tested tribologically in an N₂ atmosphere.

Each of the ion-implantation conditions affected the lubricating longevity of the PFPE. Ranked from most to least effective in prolonging longevity, the implanted species were Ti, Ti + C, unimplanted, N₂, and C \simeq Ti + N₂. In the mechanism postulated to explain these results, either a passivating or reactive layer was formed that either inhibited or facilitated, respectively, the production of harmful catalytic byproducts. The corresponding surface microstructures induced by ion implantation were obtained from x-ray diffraction and conversion electron Mossbauer spectroscopy. Ion implantation produced microstructures primarily consisting of amorphous structures. The amorphous Fe-Cr-Ti layer formed by implanting Ti ions was credited with increasing the lubricating longevity of the PFPE by an order of magnitude.

Bibliography

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